CHAPTER 4: ENGINEERING SOLUTIONS

PART I

- ❖ Introduce the concept of problem analysis and problem solving
- ❖ Learn to solve problems using an adaptation of the Engineering Method which will enable you to gradually develop an ability to solve wide range of complex solutions
- ❖ Learn a way of presenting solutions (as expected by the School of Engineering of UCSI) and the guidelines to these freehand solutions

4.1. INTRODUCTION

The practice of engineering involves the application of accumulated knowledge and experience to a wide variety of technical situations. Two areas that are fundamental to all of engineering are design and problem solving. The professional engineer is expected to intelligently and efficiently approach, analyze, and solve a wide range of technical problems.

Engineers are problem solvers – employers hire them specifically for their problem-solving skills. As essential as problem solving is, it is impossible to teach a specific approach that will always lead to a solution – the skill of problem solving is more art than science. The only way to learn problem solving is to do it – thus, your engineering education will require that you solve literally thousands of homework problems.

Problem solving is a combination of experience, knowledge, process and art. Most engineers solve many problems by process - a series of steps leading to desired results.

The following discussion provides a basic guide to problem analysis, organization and presentation.

4.2 TYPES OF PROBLEMS

❖ A problem is a situation for which there is no obvious solution.

There are many types of problems that we can confront:

- ***Research problems*** require that a hypothesis be proven or disproven. A scientist may hypothesize that CFC's (chlorofluorocarbons) are destroying the earth's ozone layer. The problem is to design an experiment that proves or disproves this hypothesis.
- ***Knowledge problems*** occur when a person encounters a situation that he does not understand. A chemical engineer may notice that the chemical plant produces more product when it rains. The cause is not immediately obvious, but further investigation might reveal that heat exchangers are cooled by the rain and hence have more capacity.
- ***Troubleshooting problems*** occur when equipment behaves in unexpected or improper ways. An electrical engineer may notice that an amplifier has a 60-cycle hum whenever the fluorescent lights are turned on. To solve this problem, she determines that extra shielding is required to isolate the electronics from the 60-cycle radiation emitted by the lights.
- ***Mathematics problems*** are frequently encountered by engineers, whose general approach

is to describe physical phenomena with mathematical models. If a mathematical model can describe a physical phenonmenon accurately, the engineer unleashes the extraordinary power of mathematics, with its rigorously proven theorems and algorithms, to help solve the problem.

- ***Resource problems*** are always encountered in the real world. It seems there is never enough time, money, people, or equipment to accomplish the task. Engineers who can get the job done in spite of resource limitations are highly prized and well rewarded.
- ***Social problems*** can impact engineers in many ways. A factory may be located where there is a shortage of skilled labour because the local schools are of poor quality. In this environment, an engineer running a training program for factory workers must design the program to accommodate the low reading abilities of the trainees.
- ***Design problems*** are the heart of engineering. To solve them requires creativity, teamwork, and broad knowledge. A design problem must be properly posed – it must include the ultimate objectives of the design project.

4.3 PROBLEM SOLVING APPROACH

❖ The approach to solving an engineering problem should proceed in an orderly, stepwise fashion. The early steps are qualitative and general, whereas the later steps are more quantitative and specific. The elements of problem solving can be describes as follows:

1. ***Problem Identification*** – This is the first step toward solving a problem.
2. ***Synthesis*** – is a creative step in which parts are integrated together to form a whole.
3. ***Analysis*** – is the step where the whole is dissected into pieces. Most of your formal education will focus on this step.
4. ***Application*** – is a process whereby appropriate information is identified for the problem at hand.
5. ***Comprehension*** – is the step in which the proper theory and data are used to actually solve the problem.

4.4 PROBLEM ANALYSIS

- A distinguishing characteristic of a qualified engineer is the ability to solve problems – which involves a combination or ***art*** and ***science***.

By ***science*** we mean knowledge of the principles of mathematics, chemistry, physics, mechanics, and other technical subjects that must be learned so that they can be applied correctly. Much of this comes from formal education.

By ***art*** we mean the proper judgment, experience, common sense, and know-how that must be used to reduce a real-life problem to such a form that science can be applied to its solution. To know when and how rigorously science should be applied and whether the resulting answer reasonably satisfies the original problem is an art. This comes about through experience and common sense. Its application, however, can be more effective if problem solving is approached in a *logical and organized manner* - that is, if it follows a process.

Problem solving is a process in which an individual or a team applies knowledge, skills, and understanding to achieve a desired outcome in an unfamiliar situation. The solution is constrained by physical, legal, and economic laws as well as by public opinion.

❖ To become a good problem solver, the engineer must have the following:

- Knowledge (first acquired in school, but later on the job).
- Experience to wisely apply knowledge.
- Learning skills to acquire new knowledge.
- Motivation to follow through on tough problems.
- Communication and leadership skills to coordinate activities within a team.

- The following table compares skilled and novice problem solvers.

Table No.1 – Comparison of Skilled and Novice Problem Solvers

Characteristic	Skilled Problem Solver	Novice Problem Solver
Approach	Motivated and persistent; logical; confident; careful.	Easily discouraged, lacks confidence; careless
Knowledge	Understands problem requirements; rereads problem; understands facts and principles	Does not understand problem requirements; relies on single reading; cannot identify facts and principles.
Attack	Breaks the problem into pieces; understands the problem before starting.	Attacks the problem all at once; tries to calculate the answer right away.

Logic	Uses basic principles; works logically from step to step.	Uses intuition and guesses, jumps around randomly.
Analysis	Organized; thinks carefully and thoroughly.	Disorganized; hopes the answer will come.
Symbols	Clearly defines terms; careful about relationships and meaning of terms.	Uncertain about the meaning of terms and symbols; jumps to unfounded conclusions about the meaning of terms.
Perspective	Has a feel for the correct magnitude of answers; understands the differences between important and unimportant issues; uses rule of thumb to estimate the answer.	Uncritically believes the answers produced by the calculator or computer; cannot differentiate between important and unimportant issues; cannot estimate the aswer.

4.5 THE ENGINEERING METHOD

- It consists of six steps:

1) ***Recognize and Understand the Problem*** - The ability to recognize and define the problem precisely is the most difficult part of problem solving. If the problem is not well defined, considerable effort must be expended at the beginning in studying the problem, eliminating the things that are not important, and focusing on the root problem.
2) ***Accumulate Data and Verify Accuracy***
3) ***Select the Appropriate Theory or Principle***
4) ***Make Necessary Assumptions***
5) ***Solve the problem***
6) ***Verify and Check Results***

4.6 PROBLEM PRESENTATION

- At UCSI, we would like the Engineering student to use an adaptation of the Engineering method in which to document the solution to problems. It consists of the following steps:

1) Problem Statement

State as concisely as possible the problem to be solved. The statement should be a summary of the given information and contain all essential information. **Clearly state what is to be determined.**

2) Diagram

Prepare a diagram (sketch) with all of the pertinent information; this is a very efficient method of showing given and needed information. Indicate all given properties on the diagram **with their units**. Label unknown quantities with a question mark.

3) Theory

The theory used should be presented. In some cases a properly referenced equation with completely defined variables is sufficient. At other times an extensive theoretical derivation may be necessary.

4) Assumptions

Explicitly list in complete detail any and all pertinent assumptions that have been made. This step is vitally important for the reader to understand the solution and its limitations.

5) Solution Steps

Show completely all steps taken in obtaining the solution. This is particularly important in an academic situation because your instructor must have the means of judging your understanding of the solution technique and principles. Steps completed but not shown make it difficult for the evaluation of your work.

5a. From the text, write the *main equation* that contains the desired quantity.

5b. Algebraically manipulate the equation to isolate the desired quantity.

5c. Write *subordinate equations* for the unknown quantities in the main equation. Indent to indicate that the equation is subordinate.

5d. After all the algebraic manipulations and substitutions are made, insert numerical values **with their units**.

5e. Ensure that units cancel appropriately. **Check for sign errors.**

6) Identify Results and Verify Accuracy

Clearly identify the final answer (double underline, arrow, etc.) and ***assign units***. **An answer without units is meaningless!!** Remember that the final step of the engineering method requires that the answer be examined to determine if it is realistic - so check the solution accuracy and, if possible, verify the result. **The final answer must make physical sense**.

4.7 STANDARD PROBLEM PRESENTATION

In engineering, it is necessary to present your solution neatly, carefully, clearly, and concisely so that the reader understands it. Therefore, it is good to have a standard format of solution presentation that will enable you to acquire the skills that will enhance your engineering work so that it is readable and understandable.

Employers insist on carefully prepared presentations that completely document all work involved in solving the problems. Thorough documentation may be important in the event of legal proceedings, for which the details of the work might be introduced into the court proceedings as evidence. Internal company use of the work is also much easier and efficient if all aspects of the work have been carefully documented and substantiated by data and theory.

❖ Based on this, the following nine general guidelines will help you develop the freehand skills needed to provide clear and complete problem documentation. **You must adhere to these guidelines for all your engineering courses at UCSI**.

1. One common type of paper used is called engineering-problem paper. It has horizontal and vertical lines on the reverse side, which are faintly visible through the paper. They help one to maintain horizontal lines of lettering and provide guides for sketching and graphing. Work must be done on one side of the page only. This type of paper is available at the bookstore. If you do not have access to any, then you must draw your own.

2. The completed top heading of the paper should include such information as name, student number, date, course number, and sheet number. The upper right corner should indicate the page number as well as the total number of pages in the assignment (i.e. 1/6 - meaning page one of six pages).

3. Work should be done in pencil using an appropriate lead hardness (F or H) so that the linework is dark, crisp and clean (unsmudged). Erasures should always be complete and the lettering and numbers should be dark enough to ensure legibility when photocopies are needed.

4. Care should be taken to produce good, legible lettering but without such care that little work is accomplished.

5. Spelling should be checked for correctness.

6. Work must be easy to follow and uncrowded. This practice contributes greatly to readability and ease of interpretation.

7. If several problems are included in a set, they must be distinctly separated. It is best to begin each problem on a fresh sheet.

8. Diagrams that are an essential part of a problem presentation should be clear and understandable. Students should strive for neatness!! Also, a little effort in preparing a sketch to approximate scale can pay great dividends when it is necessary to judge the reasonableness of an answer.

9. The proper use of symbols is always important, particularly when the International System (SI) of units is used.

The physical layout of a problem solution logically follows steps similar to those presented. An example is shown on the following page, and other examples will follow.

Sheet no.

Course No.

Due Date: 15/09/01	1302 Probs. 5.1, 5.4, 5.9	Jason H. Goodboy 99100333	1 / 3

Due date

Problems in set

Name & Student

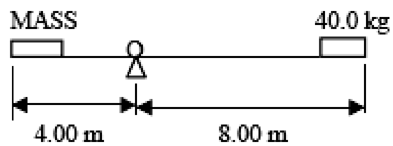
Problem identification

Number of total pages for this problem set.

PROBLEM 5.1

Problem statement

CALCULATE THE MASS NECESSARY TO BALANCE THE BEAM SHOWN



Sketch showing known data and unknown quantity.

THEORY

Engineering principle

For an object in static equilibrium, $\Sigma M_o = 0$, where M_o is the moment Produced by each force about pivot O.

ASSUMPTION

The mass of the beam is negligible.

Assumption necessary to work the problem

SOLUTION

Summing moments about O, CCW positive (Let g = accel. due to gravity)

$$\Sigma M_o = (\text{mass})g(4.00\text{ m})-(40.0\text{ kg})g(8.00\text{m}) = 0$$

Step by step solution

$$\text{mass} = (40.0\text{ kg})(8.00\text{m})/(4.00\text{m}) = \underline{\underline{80.0\text{ kg}}}$$

Double underline answer with units

Separate problems

PROBLEM 5.4

SOLVE THE FOLLOWING EQUATION FOR S : $S^2 + 5S + 6 = 0$

THEORY

Apply quadratic formula.

$$S = (-b \pm \sqrt{(b^2-4ac)})/2a \qquad \text{where } as^2 + bs + c = 0$$

SOLUTION

$$\begin{aligned} S &= (-5 \pm \sqrt{(5^2-4(1)(6))})/2(1) \\ &= (-5 \pm \sqrt{(25-24)})/2 \\ &= (-5 \pm 1)/2 = -3, -2 \end{aligned}$$

$$\underline{\underline{S = -3,\ s = -2}}$$

In this example, no assumptions or diagram are needed.

Sample Problem Presentation

	Due Date: 15/09/01	1302 Intro. to Engr. Probs.	Jason H. Goodboy 99100333	1/3
	PROBLEM 13.1 Solve for the value of resistance R in the circuit shown.